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TITLE: METHOD AND DEVICE FOR
                        DETECTING PERIOD LENGTH
                        FLUCTUATIONS OF PERIODIC
                        SIGNALS

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METHOD AND DEVICE FOR DETECTING PERIOD LENGTH FLUCTUATIONS OF PERIODIC SIGNALS

PRIORITY CLAIM

[0001] This application is the national stage application of International application number PCT/EP2003/008844, filed on August 8, 2003, which claims the benefit of priority to German Patent Application 102 39 099.1, filed on August 26, 2002, incorporated herein by reference.

BACKGROUND

[0002] 1. Technical Field

[0003] The present invention relates to a method as well as an apparatus for detecting period length fluctuations of a periodic first signal and/or of a periodic second signal, whereby the period length of the second signal is shorter than that of the first signal and a reference number of periods of the second signal, which arise during a certain number of periods of the first signal is obtained.

[0004] 2. Background Information

[0005] In the case of periodic signals disadvantageously fluctuations of the period length also arise. This can lead for example in digital technology to edge-controlled actions being triggered too early or too late causing malfunctions to arise. If for example in the case of serial data communication with data retrieval in a pre-determined cycle the analog value or the digital state of a line must be scanned, period length fluctuations of the scanning rate can lead to errors arising during data retrieval, since scanning is carried out at an incorrect time.

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[0006]   In order to measure the fluctuations of the period length of a periodic

first signal, it is known to measure the duration of a period of the first signal

several times by means of a periodic second signal, the period length of which is

shorter than the period length of the first signal. In this case, a reference number of

periods of the second signal, which arise during a period of the first signal and/or

can be inscribed in a period is obtained. The period length of the first signal

thereby corresponds to the reference number multiplied by the period length of the

second signal. In this case, a quantization error arises, since the period length of

the first signal is only resolved with an integral number of periods of the second

signal, the quantization error falling with decreasing period length of the second

signal. In addition, period length fluctuations of the second signal also have an

effect on the measurement, whereby in relation to the second signal, the

accumulated period length fluctuations make it possible to realize that in a

measurement period the period length fluctuations of the reference number are

added onto periods of the second signal. The period length fluctuations of the

second signal therefore have a greater effect on the measurement result, the higher

the reference number.

[0007]   FIG. 1 illustrates the basic principle of this measurement process. In

this case, a reference number m is defined in periods of the second signal 2, which

can be inscribed in a period of the first signal 1. The period length of the first

signal 1 is provided with the reference symbol 3 and features period length

fluctuations, which are shown as broken lines. In known methods, in order to

detect the period length fluctuations of the first signal 1, a signal 2 with very short

period length fluctuations is used, so that the period length of individual periods of the first signal 1 can be measured with high precision. Vice-versa if the signal 1 is present with high precision and very short period length fluctuations, the accumulated or added period length fluctuations of the second signal can be detected. By multiple measurements of reference numbers m, the period length fluctuations of the first signal or the accumulated period length fluctuations of the second signal can therefore be measured, dependent on what signal with high precision and/or with short period fluctuations is present.

[0008]   Disadvantageously, however, this requires at least a high precision signal with a very short period length fluctuation.

BRIEF SUMMARY

[0009]   The underlying object of the present invention is to provide a method as well as an apparatus with which period length fluctuations of a periodic first signal are measured at low cost by counting a reference number, inscribable in the period of the first signal, of periods of a higher frequent periodic second signal without requiring any high precision reference signals.

[0010]   In accordance with the invention, this object is achieved by a method with the features of Claim 1 and/or an apparatus with the features of Claim 10. The sub-claims in each case define preferred and advantageous embodiments of the present invention.

[0011]   In accordance with the present invention, the reference number of periods of the second signal, which can be inscribed in one or several periods of

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the first signal is obtained. In this case, the measurement of this reference number is carried out for two different period lengths of the second signal. Dependent on the period length of the second signal also the reference number and the effect of the period length fluctuations of the second signal on the measurement precision change.

[0012] FIG. 2 shows for a first signal with a given period length the standard deviation σ of several measurements of the period length of the first signal 1 by counting inscribable periods of the second signal 2 over the reference number m. The standard deviation σ therefore relates to the entire error of the measurement, which depends both on period length fluctuations of the first signal 1 and also on the accumulated period length fluctuation of the second signal 2. The reference number m is proportionally dependent on the reciprocal value of the period length 4 of the second signal 2. The standard deviation σ is taken into account as a measure for the period length fluctuations.

[0013] The curve in FIG. 2 can be divided into three zones A to C. In zone A on the basis of the low reference numbers m the curve of the standard deviation is essentially defined by the quantization error, which is proportional to the period length 4 of the second signal 2 and/or vice-versa proportional to the reference number m. In zone A the curve of the standard deviation falls with increasing reference numbers m and reaches its minimum in zone B.

[0014] In zone B the standard deviation is defined both by the period length fluctuations of the first signal 1 as well as of the second signal 2. With rising

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value of the period length fluctuations of the first signal 1 the curve is raised and flattened out in the zone of the minimum.

[0015] Subsequently, the curve of the standard deviation rises with increasing reference numbers m. The curve in this zone essentially behaves proportionally to the square root of the reference number m.

[0016] In accordance with the invention, the measurement is now carried out several times for two different values of the period length 4 of the second signal 2. For a certain reference number m the standard deviation σ for the entire measurement is determined as follows

[0017] $\sigma^2 = a^2 + 2ay\rho + y^2$

[0018] For roughly normally split period length fluctuations σ_1 of the first signal 1 and σ_2 of the second signal 2 a regression coefficient r can be calculated as follows

[0019] $r = \rho \cdot x$,

[0020] whereby $x = y/a$, $y = \sigma_1$ and $a = \sigma_2 \cdot \sqrt{m}$

[0021] Determination of the standard deviation σ for the entire measurement at places m0 and m>m0 leads to the equations

$$\sigma = \sqrt{\sigma_0^2 + \sigma_2^2 m_0 \frac{m}{m_0}(1+2r)(1-A)} \text{ and}$$

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$$\sigma = \sqrt{\sigma_0^2 / A - \sigma_1^2 (1 - A)/A}$$

[0022] for the period length fluctuations of the two signals 1, 2 and/or their standard deviations $\sigma^2 \cdot \sqrt{m_0}$ equal to the accumulated period length fluctuations of the second signal 2 and the period length fluctuations and/or the standard deviation of the first signal equal to σ_1 dependent on the measured quantities m_0, σ_0 and m, σ. The regression coefficient A is composed of the regression coefficients m_0, r_0 and m, r. In this case, A is calculated as follows

$$A = \left(\frac{m_0}{m}\right)\left(\frac{1 + 2r_0}{1 + 2r}\right)$$

[0023] In the following, the regression coefficients resulting thereby are shown for several ratios of m to m_0

m/m0	1,69	2,0	2,47	4,0
$\bar{r}$ $\bar{r_0} = 0,1601$	0,0323	0,0189	0,0094	0,0009
$\bar{A}$	0,7361	0,6387	0,5267	0,331

[0024] For greater clarity, FIG. 3 shows a diagram in which the standard deviation σ_B of the entire measurement for a first period length of the second signal 2 is plotted towards the right and the standard deviation σ_C of the entire measurement for a second shorter period length of the signal 2 is plotted upwards. A specific point in this diagram, for certain values of the standard deviation σ_1 of the period length fluctuation of the signal 1 and the accumulated standard deviation $\sigma_2 \sqrt{m}$ of the period length fluctuations of the second signal 2,

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reproduces the values for the standard deviations σ_B and σ_C of the entire

measurement error, which result when the measurement is carried out with the two

different period lengths 4 of the second signal 2. As an example, two groups of

lines are drawn in the diagram, which represent the standard deviations of the

entire measurement for the two period lengths of the second signal 2 in the case of

constant standard deviation σ_1 of the period fluctuation of the first signal 1 and/or

in the case of constant standard deviation $\sigma_2 \sqrt{m}$ of the accumulated period length

fluctuations of the second signal 2.

[0025]   The substantially horizontal and straight running curve family

represents the case where the standard deviation of the accumulated period length

fluctuations of the second signal 2 is constant, the direction in which the standard

deviation of the accumulated period length fluctuations of the second signal 2 rise,

being indicated with the arrow pointing upwards, which is identified with $\sigma_2 \sqrt{m}$.

[0026]   The other substantially perpendicularly running and upwards arched

curve family represents the case where the standard deviation of the period length

fluctuations of the first signal 1 is constant, the arrow pointing to the right, which

is identified with σ_1, showing the direction, in which the standard fluctuations of

the period length of the first signal 1 rise. An essentially angle-bisecting auxiliary

straight line passing through the origin is also illustrated, the slope of which is the

reciprocal value of the root of the regression coefficient A and which represents

the asymptote for the curve family for constant standard deviation σ_1 of the period

length fluctuation of the first signal 1.

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[0027] In accordance with the invention, the values for the standard deviation of the period length fluctuations of the first signal 1 as well as the standard deviation of the accumulated period length fluctuations of the second signal 2 can now be read off in the diagram for 2 values σ_B and σ_C of the standard deviation of the entire measurement for two different period lengths 4 of the second signal 2. For this purpose, the curves σ_1 =constant and $\sigma_2\sqrt{m}$ =constant, the point of intersection of which marks the wanted place in the plane σ_B, σ_C can be selected from the two curve families. These values can also be determined arithmetically using the equations

$$\sigma_{acc} = \sigma_2\sqrt{m_0} = \sqrt{\frac{\sigma^2 - \sigma_0^2}{\dfrac{m}{m_0}(1+2r)(1-A)}}$$

$$\sigma_1 = \sqrt{\frac{\sigma^2 A}{1-A}}$$

[0028] Through measurement with two different period lengths of the second signal 2 the period length fluctuations both of the first signal 1 and also in accumulated form of the second signal 2 can therefore be calculated independently of one another. This means that advantageously no high precision reference signal with especially short period length fluctuations is required.

[0029] In this way, the period length fluctuation of the first signal and/or second signal can be detected at low cost, as a result of which the method in

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accordance with the invention can also be implemented economically in integrated semiconductors as a self-test routine. For example, this is useful in the case of phase-locked loops, in order to be able to check the period length fluctuations of the output signal. Such a phase-locked loop can be used in data transmission for data retrieval in DSL data transmission systems for example.

[0030]   To implement the method in accordance with the invention, it is basically immaterial how often the measurement is carried out, since evaluation of the standard deviation as a measure for period length fluctuations concerns a statistical method, advantageously the measurements for the two different period lengths of the second signal 2 being repeated several times, in order to achieve more reliable results. Naturally, the process can therefore be run in an integrated circuit or a corresponding device controlled by a micro-program, for example whenever these are switched on.

[0031]   Up to now, the case where the measurement is only carried out for two different period lengths 4 of the second signal 2 has been described. However, in addition, it is also conceivable that three or more different values for the period length 4 of the second signal 2 are measured, as a result of which other equations follow and under certain circumstances a redundant equation system ensues, from which an optimization function may be derived, in the case of which for example the values for the period length fluctuation of the first signal 1 and the accumulated period length fluctuation of the second signal 2 can be determined according to the minimum error square method.

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BRIEF DESCRIPTION OF THE DRAWINGS

[0032]   FIG. 1 shows the time-related curves of a first and a second signal with different period lengths.

[0033]   FIG. 2 shows the curve of the standard deviation of the measurement of the period length of a signal by counting periods of the second signal with a shorter period length.

[0034]   FIG. 3 shows, for various combinations of the period length fluctuation of the first and of the second signal, the values resulting from measuring different period lengths of the second signal, and

[0035]   FIG. 4 shows the circuit diagram of an apparatus for calculating the period length fluctuations of both signals.

DETAILED DESCRIPTION

[0036]   FIG. 1 in principle shows the curve of a periodic first signal 1 and a periodic second signal 2, the first signal 1 having a period length 3, which is longer than the period length 4 of the second signal 2. The period length 3 of the first signal 1 is to be determined by counting the periods of the second signal 2, which arise during the period length 3 of the first signal 1. The number of these periods is designated in the following with m. In the case illustrated m=8.

[0037]   The period length 3 of the first signal 1 in this case features certain fluctuations, as indicated by broken lines. Equally, the period length 4 of the second signal 2 features certain fluctuations, which however are not shown in FIG. 1.

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[0038] In the following the case will be examined where the average period length of the first signal 1 is substantially constant and will be measured by means of a second signal 2 inscribable in the period length 4. When the period length 4 of the second signal 2 falls and/or the frequency of the second signal 2 rises, the number m, which is designated as reference number, must increase.

[0039] In FIG. 2 the curve of the error in this period length measurement is shown over the reference number, which vice versa is again proportional to the period length 4 of the second signal 2. As a measure for the error when determining the period length fluctuation according to the aforementioned method, the standard deviation σ of the measurement result, which ensues when the measurement is carried out several times is plotted in FIG. 2 and below. FIG. 2 shows the curve split into three zones A, B and C. In zone A the period length 4 of the second signal 2 is high, so that low values m result and therefore the standard deviation σ is predominantly determined by the quantization error, which vice versa behaves proportionally to the reference number m. Accordingly, the curve for σ falls in zone A with increasing m. In zone B the curve of the standard deviation possesses a minimum, whereby in this zone the standard deviation substantially equally depends on the period length fluctuations of the first signal 1 as well as the period length fluctuations of the second signal 2. In the case of the period length fluctuations of the second signal 2 it is to be stated that this always concerns accumulated period length fluctuations, since during a measurement length several periods of the second signal 2 arise, the period length fluctuations of which are added together.

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[0040] With increasing reference number m and/or falling period length 4 of the second signal 2 in zone C the curve of the standard deviation again rises, since in the case of high reference number m and/or high number of counted periods of the second signal 2 the effect of the period length fluctuations of the second signal 2 becomes greater. In this zone the curve behaves roughly proportionally to the square root of the reference number m.

[0041] To carry out the measurement two period lengths are now calculated, whereby the first period length is determined in such a way that the corresponding reference number m during the measurement lies at the minimum of the curve of the standard deviation σ in zone B and the second value of the period length is lower and lies in zone C. For the two values of the period length 4 of the second signal 2 the period length measurement for the first signal 1 is now carried out several times and two values for the standard deviation σ_B and σ_C are obtained, σ_B being the value of the standard deviation, which was determined for the reference number m lying in zone B. The same applies for the value σ_C.

[0042] FIG. 3 as already described above shows a diagram the surface plane of which is covered by the values for σ_B and σ_C. In this plane, the places, which in the plane of σ_B and σ_C ensue for certain value combinations for the standard deviation σ_1 of the period length fluctuation of the signal 1 and the standard deviation $\sigma^2 \sqrt{m}$ of the accumulated period length fluctuations of the second signal 2, are indicated by way of two example curve families.

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[0043] The substantially horizontal and straight running curve family represents the curves on which the standard deviation $\sigma^2 \sqrt{m}$ of the period length fluctuation of the second signal 2 is constant, whereas the curve family running substantially perpendicular and arched upwards indicates the places at which the standard deviation .sigma.1 of the period length fluctuation of the first signal 1 is constant. The arrow pointing to the right and designated with .sigma.1 indicates the direction in which the curves with a higher standard deviation of the period length fluctuation of the first signal 1 lie. The same applies for the arrow pointing upwards and designated with $\sigma^2 \sqrt{m}$ for increasing values of the standard deviation of the accumulated period length fluctuation of the second signal 2.

[0044] For the graphic solution the place, which results from the two measured values for σ_B and σ_C for the two different period lengths of the second signal 2, can be marked in this diagram shown in FIG. 3. Subsequently, it is determined which two curves of both curve families intersect at this place and depending thereon the value .sigma.1 for the standard deviation of the period length fluctuations of the first signal 1 and the value $\sigma^2 \sqrt{m}$ for the accumulated period length fluctuations of the second signal 2 can be established.

[0045] FIG. 4 shows an arithmetical solution, whereby the case is illustrated where the first signal 1 is the output signal of a phase-locked loop 5 and the second signal 2 is the output signal of a reference oscillator 6, the period length and/or frequency of which can be varied and/or at least switched between two values. The two signals 1, 2 are fed to a counter 7, which can count the number of

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periods of the second signal 2, that can be inscribed in a period of the first signal 1 and/or arise during this time-span. The circuit arrangement shown in FIG. 4 also comprises a (not illustrated) control device, which controls the various components in a suitable way. The measurements are carried out by the counter 7 for the two different values for the period length of the second signal 2 and passed onto a tabulating block 8 in which the statistical evaluation takes place. To this end for the two different period lengths of the second signal 2 the standard deviation of the measurement results and/or the counter figures calculated by the counter 7 are formed respectively in the tabulating block 8. The tabulating block 8 therefore calculates the two values σ_B and σ_C, which it passes onto an evaluation circuit 9. From the two values σ_B and σ_C this calculates the squared standard deviation and/or variance σ_1^2 and σ_2^2 for the first signal 1 and/or the second signal 2. In this case, the reference number m is considered in the evaluation block 9 and regression coefficients CB and CC which have been previously calculated arithmetically or experimentally and stored in the apparatus are also taken into account.

[0046]   The apparatus shown in FIG. 4 can be implemented in an integrated circuit for example and an estimate of the period length fluctuations of the first signal 1 of the phase-locked loop 5 can be carried out whenever the integrated circuit is switched on as self-test routine.

[0047] It is therefore intended that the foregoing detailed description be regarded as illustrative rather than limiting, and that it be understood that it is the following claims, including all equivalents, that are intended to define the spirit and scope of this invention.